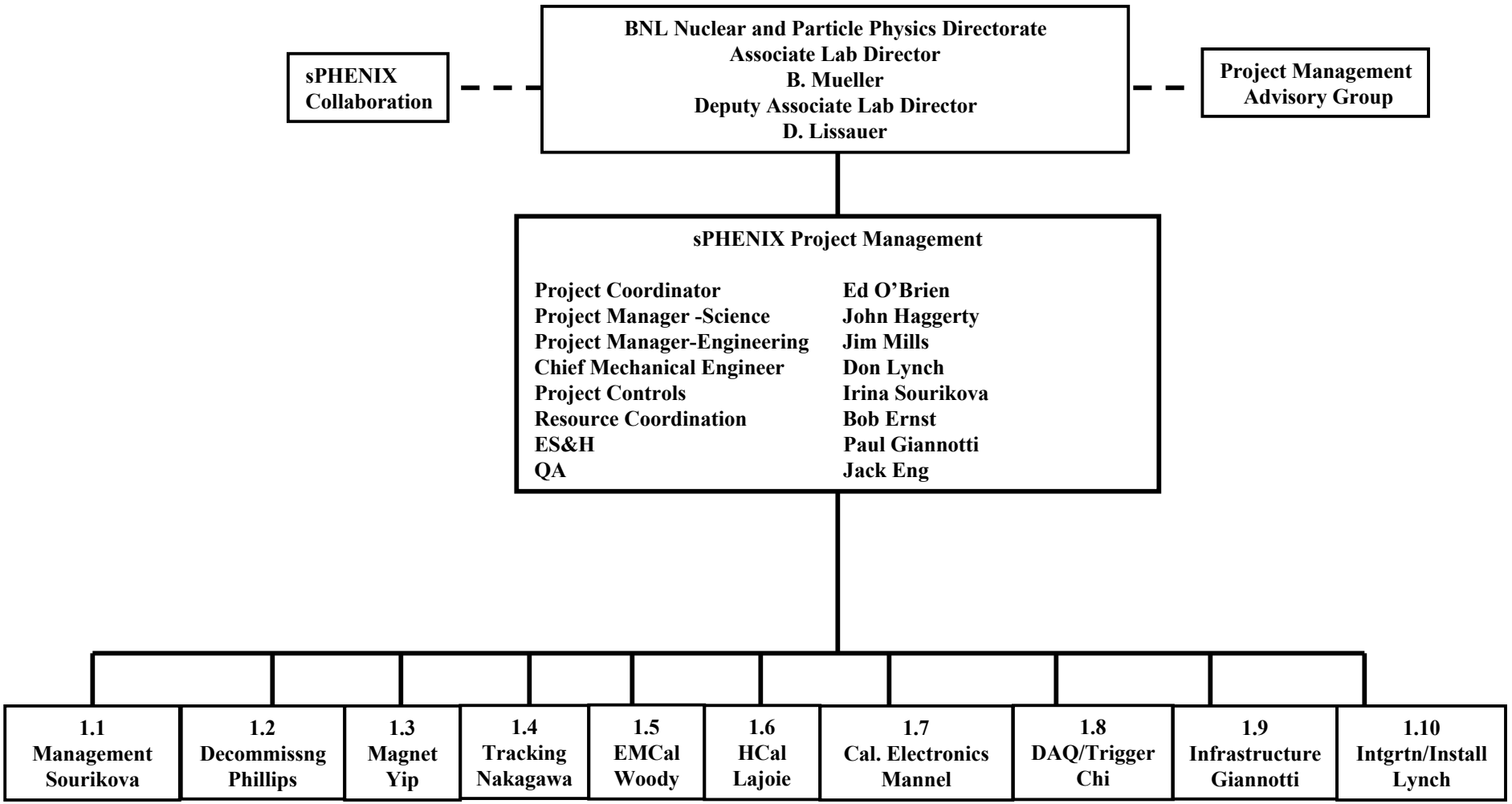
sPHENIX EMCal
Project Cost and Schedule

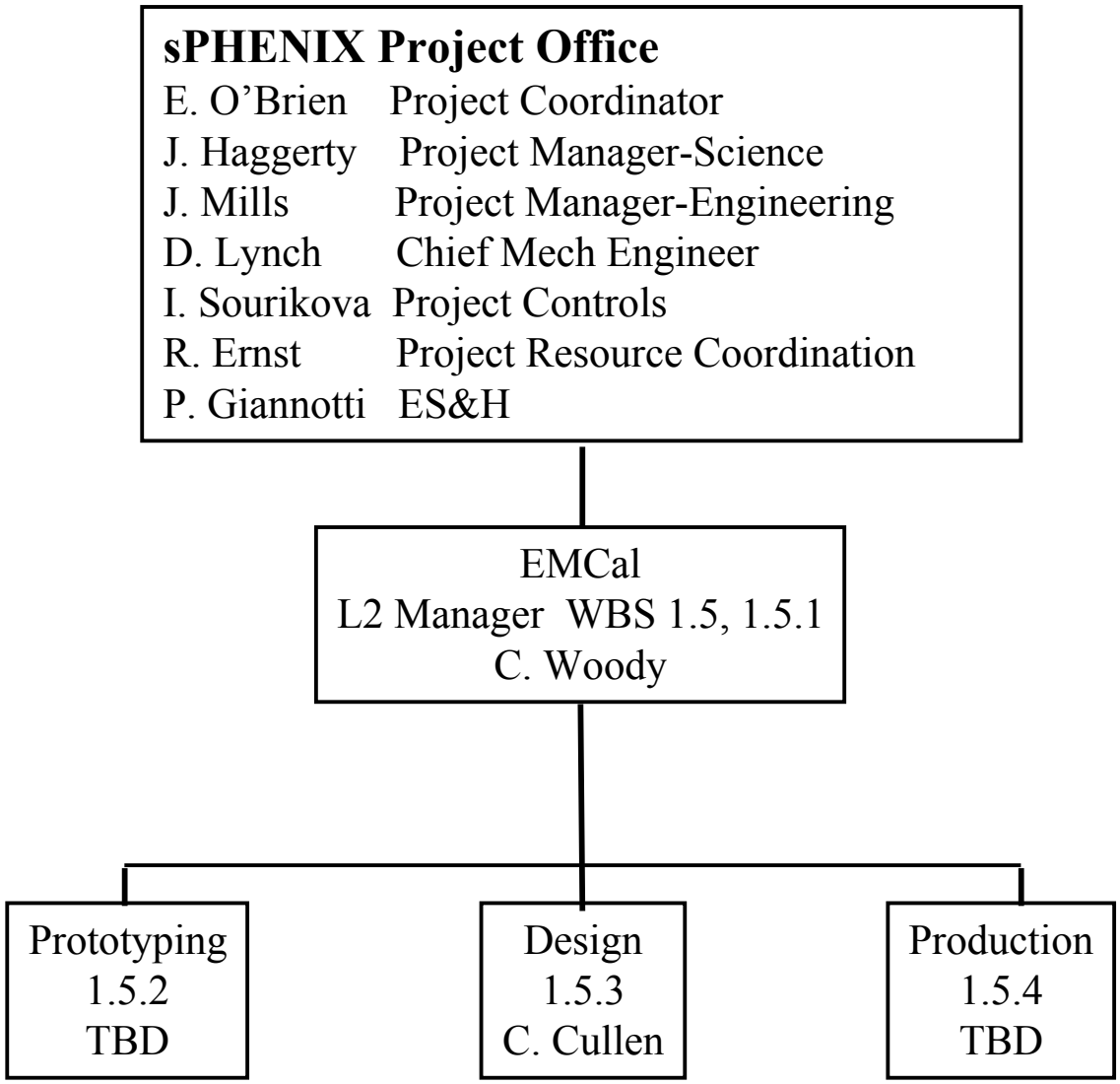
Ed O'Brien

August 20, 2015

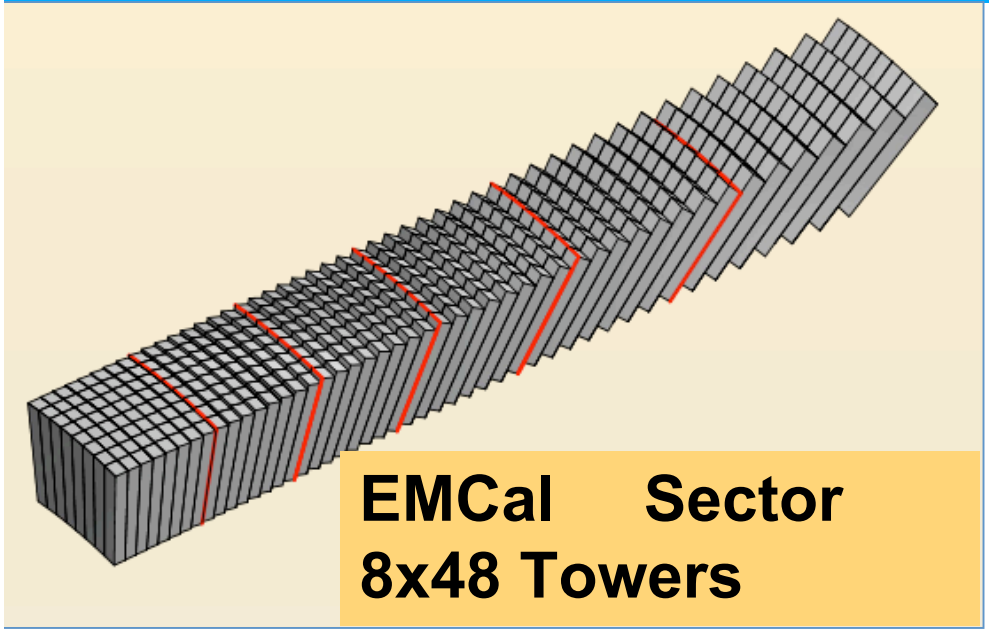
The sPHENIX Project Management Team

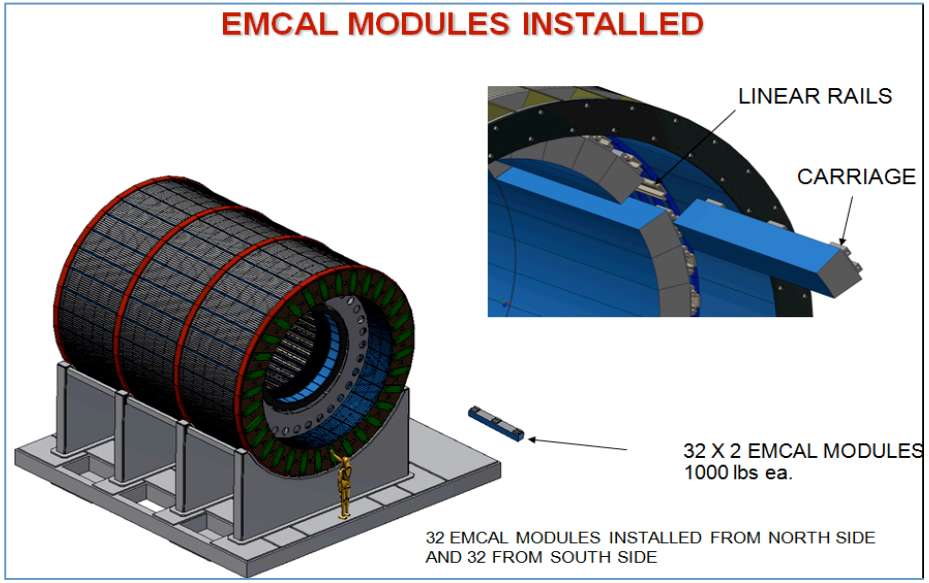


EMCal Organization



EMCal Modularity
What is the Project Scope?



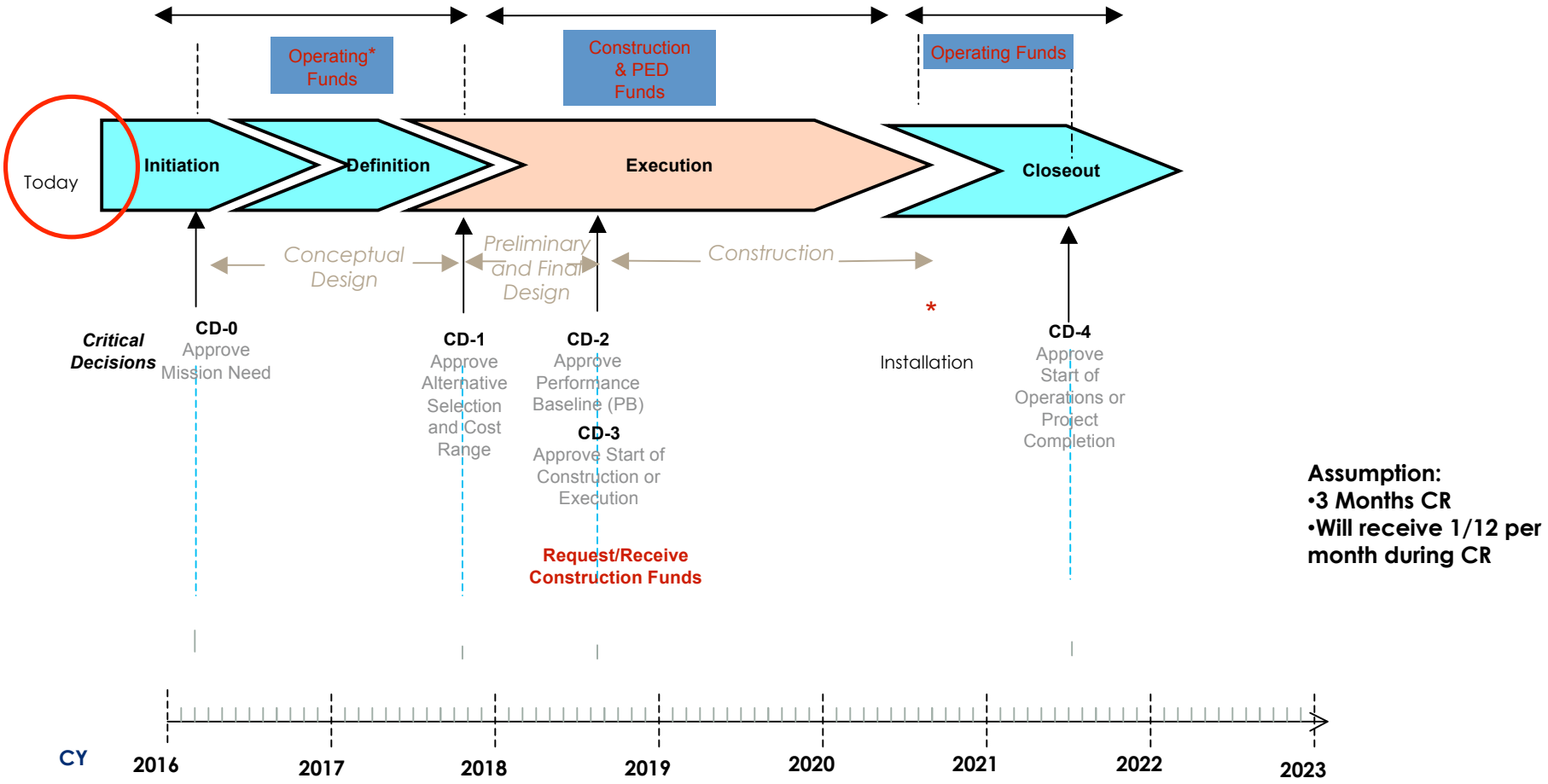


EMCAL Tungsten-scintillating fiber

- **$\Delta\eta$ x $\Delta\varphi \approx 0.025$ x 0.025**
- **96 x 256 towers**
- **4 SiPM/tower (~ 100k SiPMs total)**
- **384 towers/sector**
- **32x2 sector in the full detector**
- **EMCal $\Delta E/E < 12\%/\sqrt{E}$ (single particle)**

- **Design**
- **3 Rounds of Prototyping**
- **Fabrication and Assembly**
- **Calibration & System Integration**

sPHENIX Project Scenario



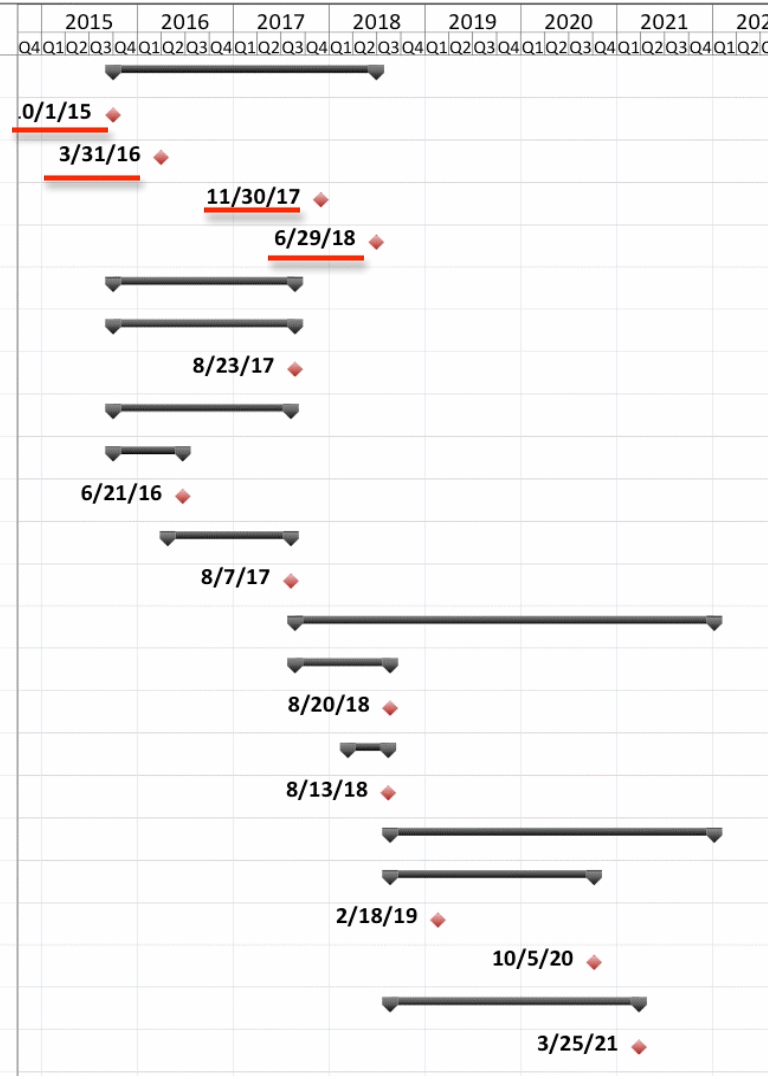
Assumption:
- **3 Months CR**
- **Will receive 1/12 per month during CR**

- Operating Funds are used for conceptual design between CD-0 and CD-1. Operating funds may also be used prior to CD-4 for R&D, NEPA, D&D, ES&H, transition, startup, and training costs. Non-federal funds from other sources that are considered capital funds and are included in the "Total line item cost" as OPC.
- Good Practice—For the first year that TEC is requested, ensure that OPC is also requested for that year. The OPC will allow the project to continue in a long CR until TEC is available and new starts are allowed.
- MIE funds are more flexible than Line Items. Moving OPC to TEC or vice versa is much easier than for Line-Item reprogramming since MIE funds are "batched."
- New Start is defined as the first use/appropriation of any TEC funds (including TEC PED) for both line items and MIEs project.

EMCal Milestone Schedule

sPHENIX PROJECT SCHEDULE (Modified to fit updated DOE/CD Milestones) Preliminary

ID	WBS	Task Name	Duration
1	**1.5.1**	**Project Milestones**	**645 days**
2	1.5.1.1	Start Pre R&D	0 days
3	1.5.1.2	Receive DOE CD-0	0 days
4	1.5.1.3	Receive DOE CD-1	0 days
5	1.5.1.4	Receive DOE CD-2/CD-3	0 days
10	**1.5.3**	**Preconceptual R&D**	**441 days**
11	**1.5.3.1**	**EMCal Preconceptual Design**	**441 days**
19	1.5.3.1.8	Complete Generic R&D Design	0 days
20	**1.5.3.2**	**EMCal Preconceptual Prototype**	**434 days**
21	**1.5.3.2.1**	**EMCal Prototype v1**	**173 days**
38	1.5.3.2.1.17	Complete v1 Prototype Work	0 days
39	**1.5.3.2.2**	**EMCal Prototype v2**	**301 days**
52	1.5.3.2.2.13	Complete v2 Prototype Work	0 days
53	**1.5.4**	**EMCal Project Tasks**	**1041 days**
54	**1.5.4.1**	**EMCal Preproduction Prototype**	**231 days**
84	1.5.4.1.31	Complete Preproduction Prototype Work	0 days
85	**1.5.4.2**	**EMCal Final Design**	**103 days**
93	1.5.4.2.8	Complete Final Design	0 days
94	**1.5.4.3**	**EMCal Production**	**810 days**
95	**1.5.4.3.1**	**EMCal Module Production**	**498 days**
102	1.5.4.3.1.7	Start Module Fabrication	0 days
106	1.5.4.3.1.11	EMCal Module Production Complete	0 days
107	**1.5.4.3.2**	**EMCal Module Assembly**	**606 days**
125	1.5.4.3.2.20	Complete Production and Assembly	0 days



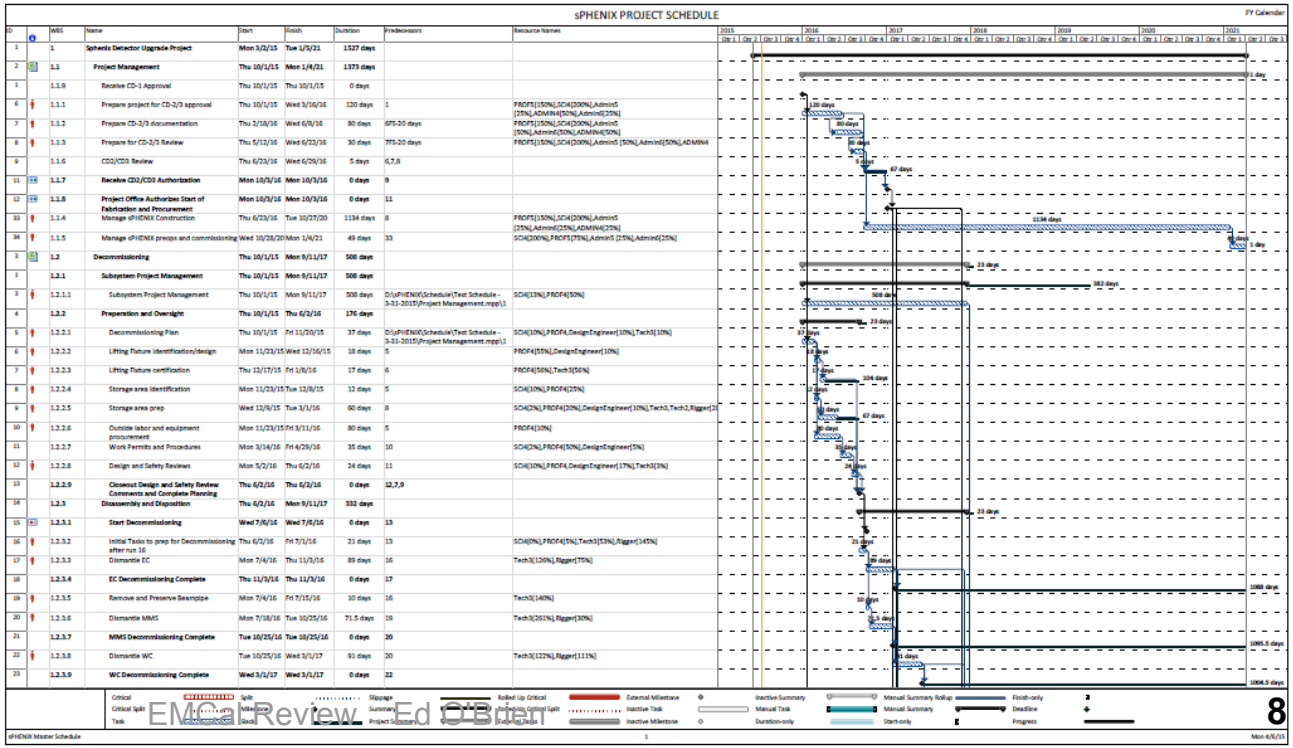
Project Schedule Summary

• **V1 prototype**	**ongoing – Jun 2016**
• **V2 prototype**	**Jun 2016 – Aug 2017**
• **Preproduction prototype**	**Aug 2017 – Aug 2018**
• **Conceptual design**	**Apr 2016 – Dec 2017**
• **Technical design**	**Dec 2017 – Jul 2018**
• **Initiate Production Orders**	**Jul 2018**
• **Tower Fabrication**	**Feb 2019 – Oct 2020**
• **Supermodule/Sector assembly**	**May 2019 – Mar 2021**
• **Ready for installation on detector**	**Mar 2021**

sPHENIX Project Planning

- **Bottoms-Up Schedule with Resources and Material Costs assigned each Task.**
  - **Each subsystem expert assigned labor by category, fixed cost and duration**
  - **Used BNL labor bands for costs**
- **All tasks are linked to create the schedule**
  - **Critical path goes through the Outer HCal design and construction**
- **> 1000 Tasks in overall schedule.**
- **Prepared Fall 2014. In the process of revising this for a Project Cost & Schedule review in November**

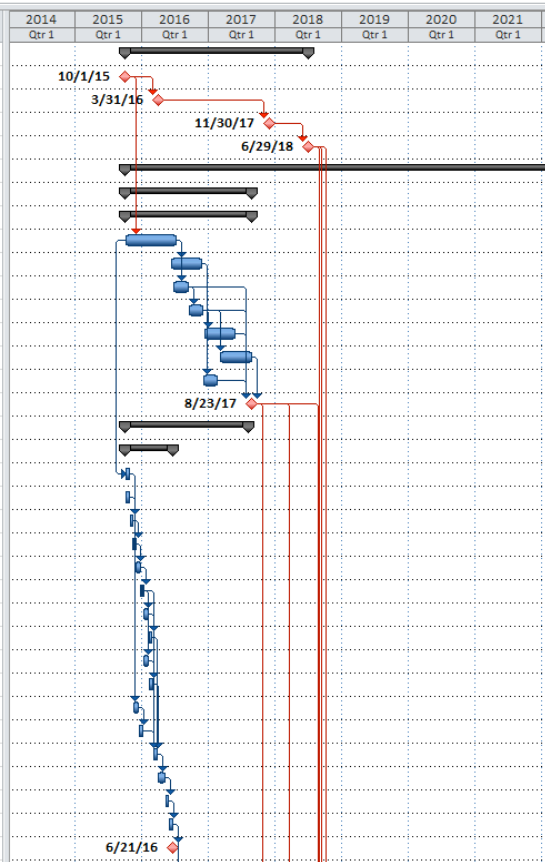
1 of 33 Project pages



Project Tasks

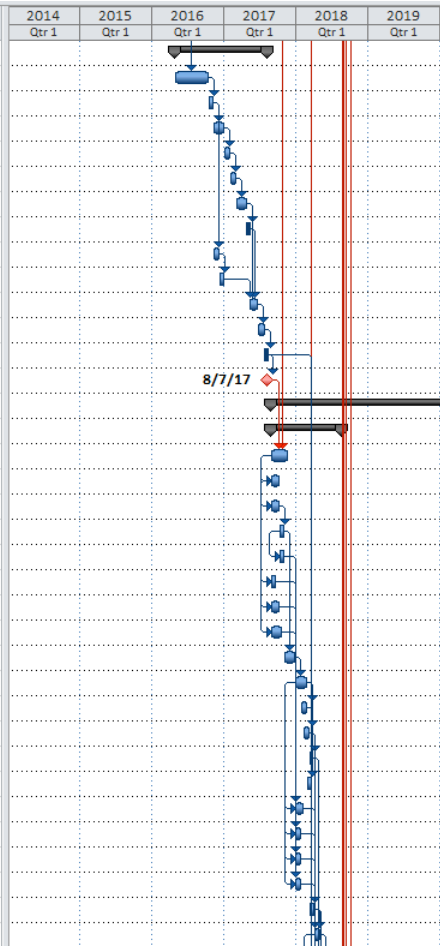
Note: We are in the process of revising our WBS organization to separate on-project tasks from off-project tasks. The WBS #'s are inconsistent between the Project file and WBS dictionary. It will be corrected in the near future.

	WBS	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Fixed Cost
1	**1.5.1**	**Project Milestones**	**645 days**	**Thu 10/1/15**	**Fri 6/29/18**			**$0**
2	1.5.1.1	Start Pre R&D	0 days	Thu 10/1/15	Thu 10/1/15			$0
3	1.5.1.2	Receive DOE CD-0	0 days	Thu 3/31/16	Thu 3/31/16	2		$0
4	1.5.1.3	Receive DOE CD-1	0 days	Thu 11/30/1	Thu 11/30/17	3		$0
5	1.5.1.4	Receive DOE CD-2/CD-3	0 days	Fri 6/29/18	Fri 6/29/18	4		$0
6	**1.5.2**	**EMCal Management**	**2023 days**	**Thu 10/1/15**	**Mon 2/5/24**			**$0**
11	**1.5.3**	**Preconceptual R&D**	**441 days**	**Thu 10/1/15**	**Wed 8/23/17**			**$0**
12	**1.5.3.1**	**EMCal Preconceptual Design**	**441 days**	**Thu 10/1/15**	**Wed 8/23/17**			**$0**
13	1.5.3.1.1	Specify R&D Generic Design	200 days	Thu 10/1/15	Wed 7/6/16	2	SCI4,SCI3,PROF3,Tech3[20%],Design2[	$0
14	1.5.3.1.2	R&D Design - mechanical support structure	125 days	Mon 6/6/16	Fri 11/25/16	13FS-20 days	SCI3[10%],PROF3[50%],Design2[50%]	$0
15	1.5.3.1.3	R&D Design - tower modules	60 days	Mon 6/20/16	Fri 9/9/16	13FS-10 days	SCI3[10%],PROF3[10%],Design1[20%]	$0
16	1.5.3.1.4	R&D Design - light collection	60 days	Mon 9/12/16	Fri 12/2/16	15	SCI3[20%],PROF2[10%],Design1[20%]	$0
17	1.5.3.1.5	R&D Design - Readout configuration	125 days	Mon 12/5/16	Fri 5/26/17	16	SCI4[20%],PROF2[20%],Design1[20%]	$0
18	1.5.3.1.6	R&D Design - calibration system	125 days	Thu 3/2/17	Wed 8/23/17	16FS+50 days	SCI3[50%],Design1[20%],PROF3[20%]	$0
19	1.5.3.1.7	R&D Design - auxillary systems (cooling, etc)	60 days	Mon 11/28/1	Fri 2/17/17	14	Design1[10%],PROF3[10%],SCI3[10%]	$0
20	1.5.3.1.8	Complete Generic R&D Design	0 days	Wed 8/23/1	Wed 8/23/17	15,16,18,19,17		$0
21	**1.5.3.2**	**EMCal Preconceptual Prototype**	**434 days**	**Thu 10/1/15**	**Mon 8/7/17**			**$0**
22	**1.5.3.2.1**	**EMCal Prototype v1**	**173 days**	**Thu 10/1/15**	**Tue 6/21/16**			**$0**
23	1.5.3.2.1.1	Design tooling to fabricate modules	20 days	Thu 10/1/15	Wed 10/28/15	13SS	PROF3[20%],Design1[20%]	$0
24	1.5.3.2.1.2	Build tooling to fabricate modules	20 days	Thu 10/1/15	Wed 10/28/15		Tech3[50%]	$3,000
25	1.5.3.2.1.3	Fabricate first modules	10 days	Thu 10/29/1	Wed 11/11/15	24	Tech3	$1,000
26	1.5.3.2.1.4	Test first modules	10 days	Thu 11/12/1	Wed 11/25/15	25	PROF3[10%],Tech3[20%]	$0
27	1.5.3.2.1.5	Fabricate modules for prototype	20 days	Thu 11/26/1	Wed 12/23/15	26	Tech3	$10,000
28	1.5.3.2.1.6	Build mechanics for prototype	10 days	Thu 12/24/1	Wed 1/6/16	27	Tech3	$2,000
29	1.5.3.2.1.7	Design light collection	20 days	Thu 1/7/16	Wed 2/3/16	28	SCI4[20%],PROF3[10%],Design1[20%],1	$0
30	1.5.3.2.1.8	Build light collection system	15 days	Thu 2/4/16	Wed 2/24/16	29	SCI3[10%],Tech3	$2,000
31	1.5.3.2.1.9	Design calibration system	20 days	Thu 1/7/16	Wed 2/3/16	28	SCI3[50%],PROF3[20%],Design1[20%],1	$0
32	1.5.3.2.1.10	Build calibration system	20 days	Thu 2/4/16	Wed 3/2/16	31	SCI3[20%],Tech3	$5,000
33	1.5.3.2.1.11	Design auxillary systems (cooling, movement,etc	20 days	Fri 11/13/15	Thu 12/10/15	23FS+10 days	SCI3[10%],PROF3[20%],Design1[20%]	$0
34	1.5.3.2.1.12	Build auxillary systems	20 days	Fri 12/11/15	Thu 1/7/16	33	Tech3	$10,000
35	1.5.3.2.1.13	Final assembly and bench tests	18 days	Thu 3/3/16	Mon 3/28/16	28,30,32,34	SCI4,Tech3[50%]	$0
36	1.5.3.2.1.14	Test prototype in test beam	30 days	Tue 3/29/16	Mon 5/9/16	35	SCI4,SCI3,PROF3	$15,000
37	1.5.3.2.1.15	Performance review v1 prototype	10 days	Tue 5/10/16	Mon 5/23/16	36	SCI4,SCI2[200%],SCI3,PROF3	$0
38	1.5.3.2.1.16	Perform 2nd test	20 days	Tue 5/24/16	Tue 6/21/16	37		$0
39	1.5.3.2.1.17	Complete v1 Prototype Work	0 days	Tue 6/21/16	Tue 6/21/16	38		$0



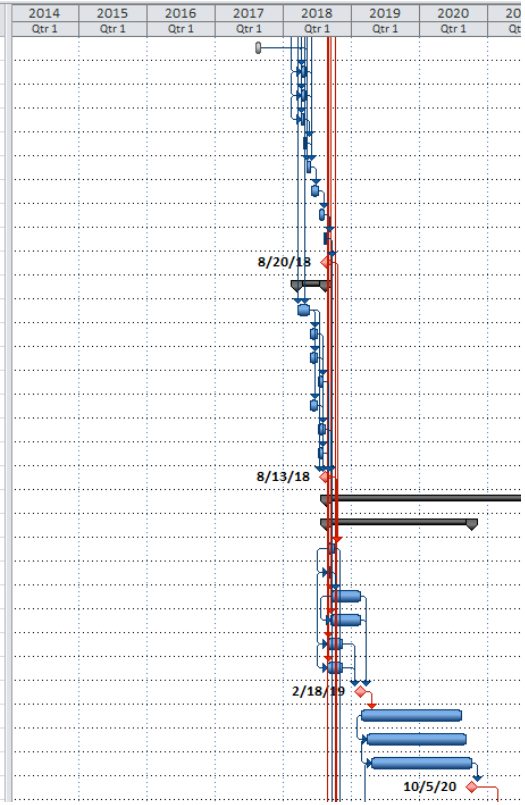
Project Tasks

	WBS	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Fixed Cost
40	**1.5.3.2.2**	**EMCal Prototype v2**	**301 days**	**Tue 4/26/16**	**Mon 8/7/17**			**$0**
41	1.5.3.2.2.1	Develop procedure for building fully projective n	120 days	Tue 4/26/16	Mon 10/10/16	38FS-40 days	SCI4,SCI2,PROF3[10%],Design1[20%],T	$30,000
42	1.5.3.2.2.2	Design mechanics for fully projective prototype	20 days	Tue 10/11/1	Mon 11/7/16	41	Design1[50%],PROF3[50%]	$0
43	1.5.3.2.2.3	Build tooling to fabricate modules	40 days	Tue 11/8/16	Mon 1/2/17	42	Tech3[50%]	$5,000
44	1.5.3.2.2.4	Fabricate first modules	20 days	Tue 1/3/17	Mon 1/30/17	43	Tech3	$2,000
45	1.5.3.2.2.5	Test first modules	20 days	Tue 1/31/17	Mon 2/27/17	44	SCI4[20%],Tech3[20%]	$0
46	1.5.3.2.2.6	Fabricate modules for prototype	40 days	Tue 2/28/17	Mon 4/24/17	45	Tech3	$10,000
47	1.5.3.2.2.7	Build mechanics for prototype	10 days	Tue 4/25/17	Mon 5/8/17	46	Tech3	$2,000
48	1.5.3.2.2.8	Design light collection system	20 days	Tue 11/8/16	Mon 12/5/16	42	SCI3[50%],PROF3[20%],Design1[20%],T	$0
49	1.5.3.2.2.9	Build light collection system	20 days	Tue 12/6/16	Mon 1/2/17	48	Tech3,SCI3[20%]	$5,000
50	1.5.3.2.2.10	Assemble prototype and bench test	30 days	Tue 5/9/17	Mon 6/19/17	47,46,49	Tech3,SCI3	$0
51	1.5.3.2.2.11	Test prototype in test beam	25 days	Tue 6/20/17	Mon 7/24/17	50	SCI3,SCI4,PROF3	$15,000
52	1.5.3.2.2.12	Performance review v2 prototype	10 days	Tue 7/25/17	Mon 8/7/17	51	SCI2[200%],SCI3,SCI4,PROF3	$0
53	1.5.3.2.2.13	Complete v2 Prototype Work	0 days	Mon 8/7/17	Mon 8/7/17	52		$0
54	**1.5.4**	**EMCal Project Tasks**	**1041 days**	**Thu 8/24/17**	**Thu 1/6/22**			**$0**
55	**1.5.4.1**	**EMCal Preproduction Prototype**	**231 days**	**Thu 8/24/17**	**Mon 8/20/18**			**$0**
56	1.5.4.1.1	Design mechanical components	60 days	Thu 8/24/17	Wed 11/15/17	20,53FS-10 days	SCI3[20%],PROF2[50%],Design1[50%]	$0
57	1.5.4.1.2	Design tower structure	30 days	Thu 8/24/17	Wed 10/4/17	56SS	SCI3[20%],PROF2[20%],Design1[20%]	$0
58	1.5.4.1.3	Design tooling for mass production of prototype mc	30 days	Thu 8/24/17	Wed 10/4/17	57SS	SCI3[10%],Design1[20%],PROF3[20%]	$0
59	1.5.4.1.4	Design tooling for assembly and testing	20 days	Thu 10/5/17	Wed 11/1/17	58	SCI3[10%],Design1[20%],PROF3[20%]	$0
60	1.5.4.1.5	Design light collection system	20 days	Thu 10/5/17	Wed 11/1/17	59SS	PROF3[20%],Design1[20%],SCI3[20%]	$0
61	1.5.4.1.6	Design readout system	20 days	Thu 8/24/17	Wed 9/20/17	56SS	PROF3[20%],Design1[20%],SCI3[20%]	$0
62	1.5.4.1.7	Design calibration system	30 days	Thu 8/24/17	Wed 10/4/17	56SS	PROF3[20%],Design1[20%],SCI3[20%]	$0
63	1.5.4.1.8	Design auxillary systems (cooling, movement,etc)	40 days	Thu 8/24/17	Wed 10/18/17	56SS	SCI3[10%],Design1[20%],PROF3[20%]	$0
64	1.5.4.1.9	Fabricate tooling for modules	40 days	Thu 11/2/17	Wed 12/27/17	59	Tech3	$10,000
65	1.5.4.1.10	Fabricate modules	40 days	Thu 12/28/1	Wed 2/21/18	64	Tech3,Tech1,STUDENT[200%]	$116,000
66	1.5.4.1.11	Test modules in factory	20 days	Wed 1/24/1	Tue 2/20/18	65FS-20 days	Tech3,STUDENT	$0
67	1.5.4.1.12	Test modules as delivered	20 days	Tue 2/6/18	Mon 3/5/18	66FS-10 days	Tech3,STUDENT	$0
68	1.5.4.1.13	Build mechanical mock up	15 days	Tue 3/6/18	Mon 3/26/18	67	SCI3[10%],Tech1	$3,000
69	1.5.4.1.14	Build mechanical structure of prototype	20 days	Thu 2/22/18	Wed 3/21/18	65	SCI3[10%],Tech3,Tech1	$10,000
70	1.5.4.1.15	Build light collection system	30 days	Thu 12/28/1	Wed 2/7/18	65SS,60	SCI3[10%],Tech1	$60,000
71	1.5.4.1.16	Build readout system	20 days	Thu 12/28/1	Wed 1/24/18	65SS,61	SCI3[10%],Tech1	$10,000
72	1.5.4.1.17	Build calibration system	20 days	Thu 12/28/1	Wed 1/24/18	65SS,62	SCI3[20%],Tech1	$10,000
73	1.5.4.1.18	Build auxillary systems	20 days	Thu 12/28/1	Wed 1/24/18	65SS,63	Tech1,SCI3[10%]	$10,000
74	1.5.4.1.19	Install modules in mechanical support	20 days	Tue 3/6/18	Mon 4/2/18	67	SCI3[10%],Tech1[50%]	$0
75	1.5.4.1.20	Install light collectors	20 days	Tue 4/3/18	Mon 4/30/18	74,70	SCI3[10%],Tech1[50%]	$0



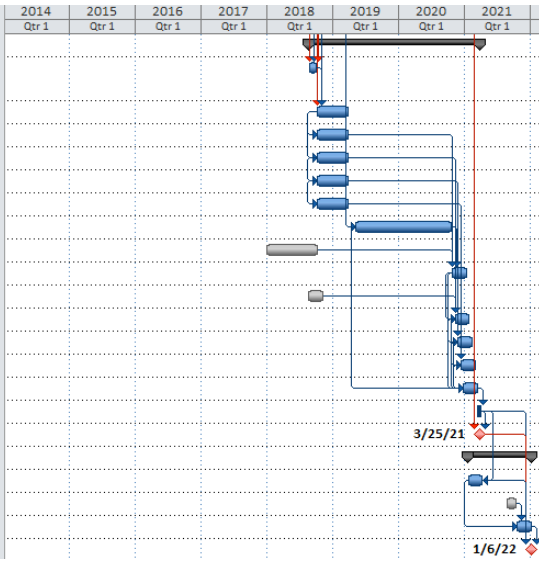
Project Tasks

	WBS	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Fixed Cost
76	1.7.3.2.3.4	Assemble and test prototype electronics: preprodu	20 days	Thu 8/3/17	Wed 8/30/17			$5,000
77	1.5.4.1.23	Install readout system	20 days	Tue 4/3/18	Mon 4/30/18	75SS,71,D:\sPHEN	SCI3[20%],Tech1[50%]	$0
78	1.5.4.1.24	Install calibration system	20 days	Tue 4/3/18	Mon 4/30/18	77SS,72	SCI3[50%],Tech1[50%]	$0
79	1.5.4.1.25	Install auxillary systems	10 days	Tue 4/3/18	Mon 4/16/18	78SS,73	SCI3[10%],Tech1[50%]	$0
80	1.5.4.1.26	Safety Review	10 days	Tue 4/17/18	Mon 4/30/18	79	SCI4,PROF3	$0
81	1.5.4.1.27	Perform final assembly	20 days	Tue 5/1/18	Mon 5/28/18	80,74,75,77,78,D:\	PROF3,SCI3,Tech1,Tech3	$0
82	1.5.4.1.28	Test prototype in lab	30 days	Tue 5/29/18	Mon 7/9/18	81	PROF3,SCI3,SCI4	$0
83	1.5.4.1.29	Test prototype in beam	20 days	Tue 7/10/18	Mon 8/6/18	82	PROF3,SCI3,SCI4	$20,000
84	1.5.4.1.30	Performance review of preproduction prototype	10 days	Tue 8/7/18	Mon 8/20/18	83	SCI2[200%],SCI3,SCI4,PROF3	$0
85	1.5.4.1.31	Complete Preproduction Prototype Work	0 days	Mon 8/20/18	Mon 8/20/18	84		$0
86	**1.5.4.2**	**EMCal Final Design**	**103 days**	**Tue 3/13/18**	**Mon 8/13/18**			**$0**
87	1.5.4.2.1	Specify Final Design Parameters	50 days	Tue 3/13/18	Mon 5/21/18	52,20,68FS-10 day:	SCI4,SCI3,PROF3,Tech3[20%],Design2[:	$0
88	1.5.4.2.2	Final Design - mechanical support structure	30 days	Tue 5/22/18	Mon 7/2/18	87	SCI3[10%],PROF3[50%],Design2[50%]	$0
89	1.5.4.2.3	Final Design - tower modules	30 days	Tue 5/22/18	Mon 7/2/18	87	SCI3[10%],PROF3[10%],Design1[20%]	$0
90	1.5.4.2.4	Final Design - light collection	20 days	Tue 7/3/18	Mon 7/30/18	89	SCI3[20%],PROF2[10%],Design1[20%]	$0
91	1.5.4.2.5	Final Design - Readout configuration	30 days	Tue 5/22/18	Mon 7/2/18	87	SCI4[20%],PROF2[20%],Design1[20%]	$0
92	1.5.4.2.6	Final Design - calibration system	30 days	Tue 7/3/18	Mon 8/13/18	91	SCI3[50%],Design1[20%],PROF3[20%]	$0
93	1.5.4.2.7	Final Design - auxillary systems (cooling, etc)	20 days	Tue 7/3/18	Mon 7/30/18	88	Design1[10%],PROF3[10%],SCI3[10%]	$0
94	1.5.4.2.8	Complete Final Design	0 days	Mon 8/13/18	Mon 8/13/18	87,88,89,90,91,92,'		$0
95	**1.5.4.3**	**EMCal Production**	**810 days**	**Tue 8/21/18**	**Thu 1/6/22**			**$0**
96	**1.5.4.3.1**	**EMCal Module Production**	**498 days**	**Tue 8/21/18**	**Mon 10/5/20**			**$0**
97	1.5.4.3.1.1	Update Design for Fabrication and Assembly	30 days	Tue 8/21/18	Mon 10/1/18	85,94	SCI3[10%],PROF3[20%],Design1[20%]	$0
98	1.5.4.3.1.2	Production Readiness and Safety Review	10 days	Tue 8/21/18	Mon 9/3/18	97SS	SCI3[50%],PROF3[50%],Design1[20%],1	$0
99	1.5.4.3.1.3	Procurement of calorimeter materials	120 days	Tue 9/4/18	Mon 2/18/19	98,5	SCI3[20%],PROF3[20%]	$0
100	1.5.4.3.1.4	Establish Fabrication contract	120 days	Tue 9/4/18	Mon 2/18/19	99SS,5	PROF2[10%]	$0
101	1.5.4.3.1.5	Fabricate tooling for mass production	60 days	Tue 8/21/18	Mon 11/12/18	98SS,5	Tech1,Tech3	$50,000
102	1.5.4.3.1.6	Set up factory for mass production	60 days	Tue 8/21/18	Mon 11/12/18	101SS,5	Tech1,Tech3	$20,000
103	1.5.4.3.1.7	Start Module Fabrication		Mon 2/18/19	Mon 2/18/19	99,101,102,100		$0
104	1.5.4.3.1.8	Fabricate modules	385 days	ue 2/19/19	Mon 8/10/20	103	SCI3[50%],Tech3,Tech2,Tech1[600%],S	$3,680,000
105	1.5.4.3.1.9	Test modules in factory	385 days	e 3/19/19	Mon 9/7/20	104SS+20 days	SCI3[50%],Tech2,STUDENT[200%]	$10,000
106	1.5.4.3.1.10	Test modules as delivered	385 days	ue 4/16/19	Mon 10/5/20	105SS+20 days	SCI3[50%],STUDENT[200%],Tech1[50%]	$10,000
107	1.5.4.3.1.11	EMCal Module Production Complete	0 days	Mon 10/5/20	Mon 10/5/20	106		$0



Project Tasks

	WBS	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Fixed Cost
108	**1.5.4.3.2**	**EMCal Module Assembly**	**606 days**	**Tue 8/21/18**	**Thu 3/25/21**			**$0**
109	1.5.4.3.2.1	Update any design changes based on FS prototype, Factory Input and Final Design	30 days	Tue 8/21/18	Mon 10/1/18	84,20,94	SCI3[20%],PROF3[50%],Design1[50%]	$0
110	1.5.4.3.2.2	Fabricate mechanical parts	125 days	Tue 10/2/18	Mon 3/25/19	109,97,5	Tech3,Tech2,Tech1[200%]	$250,000
111	1.5.4.3.2.3	Fabricate parts for light collection system	125 days	Tue 10/2/18	Mon 3/25/19	110SS	Tech1[200%]	$75,000
112	1.5.4.3.2.4	Fabricate parts for readout system	125 days	Tue 10/2/18	Mon 3/25/19	110SS	Tech1[200%]	$50,000
113	1.5.4.3.2.5	Fabricate parts for calibration system	125 days	Tue 10/2/18	Mon 3/25/19	112SS	Tech1[200%]	$50,000
114	1.5.4.3.2.6	Fabricate parts for auxillary systems	125 days	Tue 10/2/18	Mon 3/25/19	113SS	Tech1	$50,000
115	1.5.4.3.2.7	Install modules in supermodule	385 days	Tue 4/30/19	Mon 10/19/20	106SS+10 days	SCI3[50%],Tech3,STUDENT[200%]	$0
116	1.7.2.2.12	Q/A delivered EMCal production sensors	200 days	Thu 12/28/1	Wed 10/3/18			$5,000
117	1.5.4.3.2.10	Install light collectors on each supermodule	60 days	Tue 10/20/2	Mon 1/11/21	115,111,D:\sPHEN	SCI3[50%],Tech3,STUDENT[200%]	$0
118	1.7.3.3.5	Q/A EMCal electronics	60 days	Thu 8/16/18	Wed 11/7/18			$5,000
119	1.5.4.3.2.13	Install readout system on each supermodule	60 days	Tue 11/3/20	Mon 1/25/21	117SS+10 days,112	SCI3[50%],Tech3,STUDENT[200%]	$0
120	1.5.4.3.2.14	Install calibration system on each supermodule	60 days	Wed 11/18/:	Tue 2/9/21	119SS+10 days,113	SCI3[50%],Tech3,STUDENT[200%]	$0
121	1.5.4.3.2.15	Install auxillary system on each supermodule	60 days	Fri 12/4/20	Thu 2/25/21	120SS+10 days,114	SCI3[20%],Tech1[50%],STUDENT[200%]	$0
122	1.5.4.3.2.16	Perform final assembly of each supermodule	60 days	Fri 12/18/20	Thu 3/11/21	121SS+10 days,115	SCI3,PROF3,Tech2,STUDENT[200%]	$0
123	1.5.4.3.2.17	Installation readiness review	10 days	Fri 3/12/21	Thu 3/25/21	122	SCI4,SCI3,SCI2[200%],PROF3	$0
126	1.5.4.3.2.20	Complete Production and Assembly	0 days	Thu 3/25/21	Thu 3/25/21	123,107		$0
127	**1.5.4.3.3**	**EMCal Module Testing/Calibration/Integration**	**252 days**	**Fri 1/15/21**	**Thu 1/6/22**			**$0**
128	1.5.4.3.3.1	Test all supermodules individually	60 days	Fri 1/15/21	Thu 4/8/21	123FF+10 days	SCI4,PROF3,STUDENT[400%],Tech2	$0
129	1.10.03.06.06	Install EMCal cables and services	40 days	Fri 8/20/21	Thu 10/14/21			$500
130	1.5.4.3.3.4	Test all supermodules after installation	60 days	Fri 10/15/21	Thu 1/6/22	128SS+10 days,D:\	SCI4,PROF3,STUDENT[400%],Tech2	$0
131	1.5.4.3.3.5	Complete EMCal Subsystem	0 days	Thu 1/6/22	Thu 1/6/22	123,128,130,126		$0



WBS Dictionary

sPHENIX	03/06/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.1	EMCAL Management

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description
COST CONTENT: TECHNICAL SCOPE: Management of the EMCAL system contains oversight of the construction project as well as coordination with the experimental collaboration and making certain that the as-built detector configuration is capable of carrying out the physics program of the collaboration. Preparation of cost and schedule data for design, safety, and installation reviews as well as for monitoring the progress of the construction is captured in this WBS. WORK STATEMENT: • Preparation of documentation for reviews. • Preparation of cost and schedule data.

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.2	EMCAL design

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description
COST CONTENT: TECHNICAL SCOPE: This work package captures the entire Electromagnetic Calorimeter design, including the design of all mechanical and support systems, the tungsten powder, epoxy, and scintillating fiber absorber, the light collection and readout systems, and all auxiliary systems such as calibration and cooling. WORK STATEMENT: • Mechanical design of the EMCAL, including interfaces with the Installation and Infrastructure task, which will provide mechanical support and assembly methodology for the EMCAL inside the solenoid, will be fully captured by this WBS item. • Analysis of the structure including gravitational loading and static and dynamic forces on the structure from the magnetic field. • Design of cable management for signal and bias voltage cables exiting the detector volume. • Design of the tungsten powder epoxy scintillating fiber absorber and its light guides, including whatever components are needed to connect the SiPM's to the light guides. • Preparation of all documentation for design and safety reviews. • Carry out design and safety reviews for the EMCAL.

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.3.1	EMCAL prototype v1

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

TECHNICAL SCOPE:

This work package consists of all activities and materials needed to build a first prototype of the Electromagnetic Calorimeter. The prototype will consist of a matrix of tungsten powder and epoxy with embedded scintillating fibers that is divided into approximately 2x2 cm2 towers that are read out with silicon photomultipliers (SiPMs). The deliverable resulting from this work will be a 4x6 array of towers that are projective in one direction. The resulting prototype will be capable of being coupled to the digitizer system being developed for sPHENIX (which is not part of the technical scope of this WBS line). The prototype will be capable of measuring electron energies up to 32 GeV and will include a light pulser calibration system for monitoring the gain of each channel. Design of electronics and cabling for this prototype is not part of the technical scope, but are provided by the calorimeter electronics design and prototyping tasks.

The test program will consist of testing with the light pulser system and cosmic ray triggers. Operation in a beamline, most likely the Fermilab Test Beam Facility, will be carried out in concert with the Inner and Outer HCAL prototypes.

WORK STATEMENT:

- Mechanical design of the absorber modules which will be constructed in 1x2 tower blocks
- Design of light pulser calibration system
- Procurement of the tungsten powder, epoxy and scintillating fibers.
- Procurement of light guides for towers
- Procurement of parts for light pulser calibration system
- Procurement of light tight enclosure
- Design and fabrication of miscellaneous mechanical parts
- Fabrication of the twelve 1x2 tower blocks
- Assembly of the 4x6 tower array
- Installation of light guides, SiPMs and readout electronics
- Final assembly of prototype
- Lab testing of prototype with light flasher system and cosmic rays
- Beam test of prototype

All design work needed to fabricate a prototype calorimeter is captured by this WBS line. A minimal amount of engineering is expected to be required because the prototype is relatively small.

Procurement of all the mechanical components of the prototype calorimeter is captured by this WBS item.

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.4.1	EMCAL module production

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

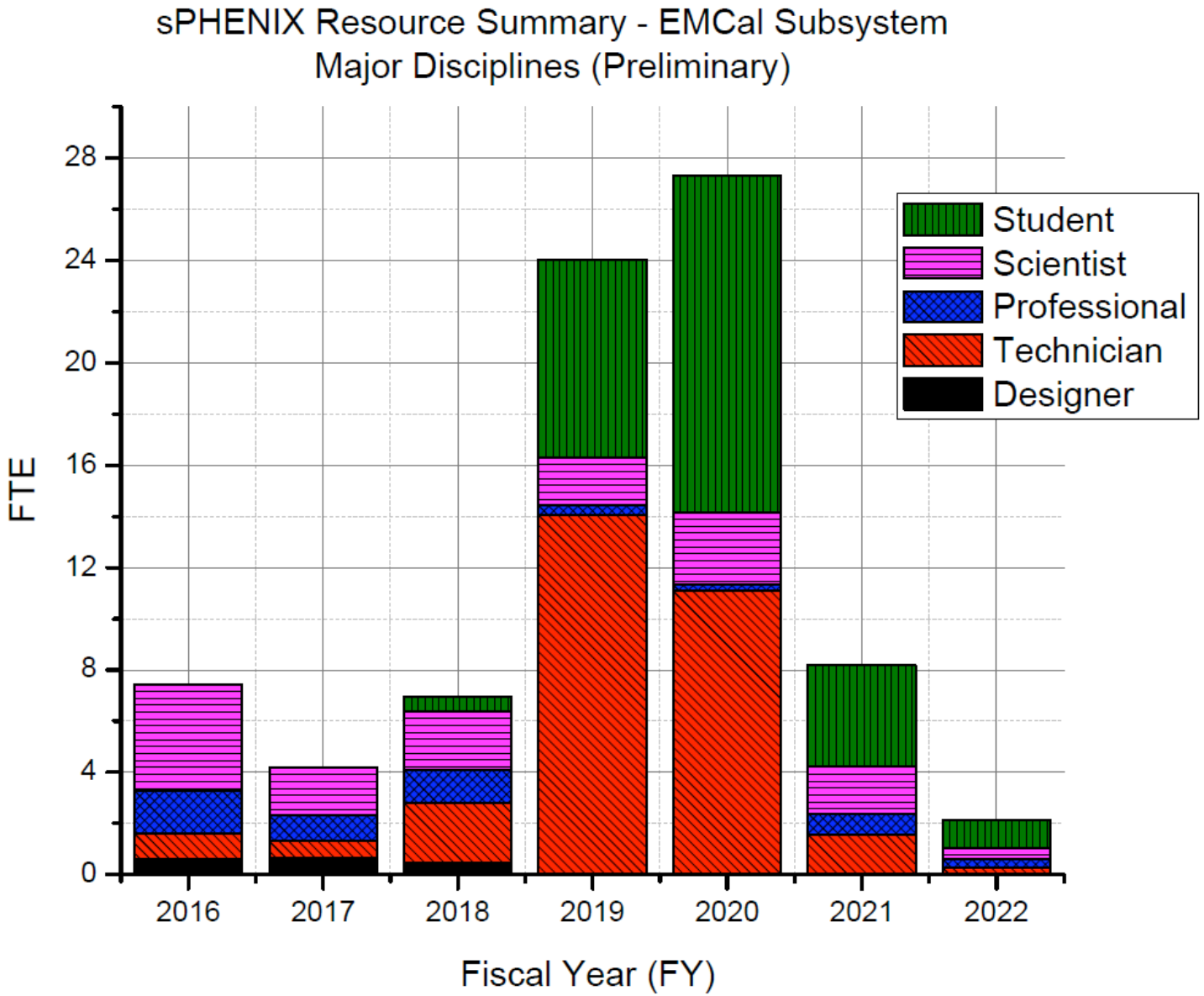
TECHNICAL SCOPE:

EMCAL module production consists of all activities needed to take the EMCAL design (completed under WBS item 1.5.2) and complete the construction of all modules required for the 64 sectors of the final calorimeter that can be delivered to the sPHENIX Assembly Hall for installation in the detector. Since design activities will be complete, this WBS line captures the effort needed to actually produce the modules, including the manufacture of any additional handling fixtures. Procurement and delivery of all materials needed to fabricate the modules are contained in this WBS line, including the production of the light guides and any assemblies needed to couple the photodetectors to the light guides.

WORK STATEMENT:

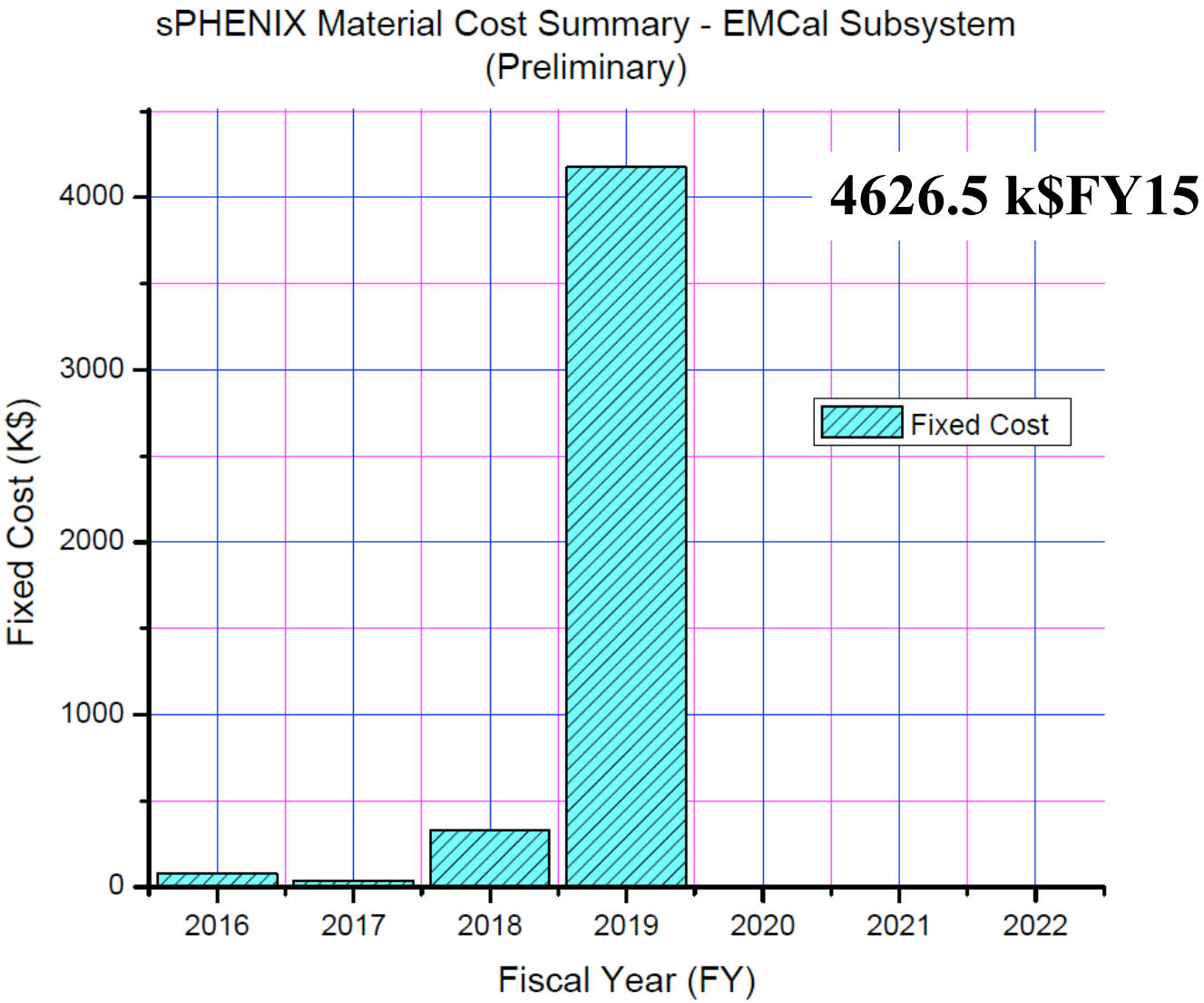
- Procurement and acceptance verification of parts needed to construct the EMCAL modules, including
  - Tungsten powder and epoxy absorber
  - Scintillating fibers
  - Light collection hardware
  - Cable management hardware
- Preparation of workspaces need for assembly of EMCAL modules
- Preparation of any storage needed while modules await assembly

EMCal Labor Profile



Estimated Budget Authority Profile

Direct Costs. No Overhead and No Contingency



EMCal Fixed Cost Breakdown

Task	FY	Total (FY15$)
EMCal Prototype v1	2016	$48,000
EMCal Prototype v2	2017	$69,000
EMCal Preproduction Prototype	2018	$254,000
Fabricate tooling for mass production	2018	$50,000
Set up factory for mass production	2018	$20,000
Fabricate modules	2019	$3,680,000
Test modules in factory	2019	$10,000
Test modules as delivered	2019	$10,000
Fabricate mechanical parts	2019	$250,000
Fabricate parts for light collection system	2019	$75,000
Fabricate parts for readout system	2019	$50,000
Fabricate parts for calibration system	2019	$50,000
Fabricate parts for auxillary systems (cooling)	2019	$50,000

Issues and Concerns

- **The EMCal is close to the project critical path which is currently understood to be the HCal. The EMCal is only behind the HCal by a couple of months.**
  - **Would like to shorten the fab time from the initial estimate**
- **EMCal tower and supermodule production plan: universities vs industry is not yet decided.**
- **A number of technical issues would potentially affect the cost estimate.**
  - **Final manufacturing technique of towers and fab time/tower**
  - **1-D vs 2-D projective could have impact on fixturing costs**
- **Availability of the number of technicians and students needed in FY19 and FY20 may be a challenge.**

Back Up

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.3.2	ECAL prototype v2

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

TECHNICAL SCOPE:

This work package consists of all activities and materials needed to build a second prototype of the Electromagnetic Calorimeter. The prototype will consist of a matrix of tungsten powder and epoxy with embedded scintillating fibers that is divided into approximately 2x2 cm2 towers that are read out with silicon photomultipliers (SiPMs). The deliverable resulting from this work will be an array of towers that are projective in two directions (azimuth and pseudorapidity η). The resulting prototype will be capable of being coupled to the digitizer system being developed for sPHENIX (which is not part of the technical scope of this WBS line). The prototype will be capable of measuring electron energies up to 32 GeV and will include a light pulser calibration system for monitoring the gain of each channel. Design of electronics and cabling for this prototype is not part of the technical scope, but are provided by the calorimeter electronics design and prototyping tasks.

The second EMCAL prototype will be designed to test the response of a fully projective calorimeter. This WBS line differs from the first v1 prototype insofar as it allows testing near the maximum pseudorapidity subtended by the final calorimeter, i.e., near $\eta \sim 1$, equivalent to a polar angle of about 40°. It may require several different tower arrays in order to accomplish this.

The test program will consist of testing with the light pulser system and cosmic ray triggers. Operation in a beamline, most likely the Fermilab Test Beam Facility, will be carried out in concert with the Inner and Outer HCAL prototypes.

WORK STATEMENT:

- Mechanical design of the 2D projective tower modules
- Develop procedure for producing 2D projective modules
- Make any design modifications of the light pulser calibration system
- Procurement of the tungsten powder, epoxy and scintillating fibers.
- Procurement of light guides for towers
- Procurement of any additional parts for light pulser calibration system
- Procurement of light tight enclosure and support structure
- Fabrication of the tower modules
- Assembly of tower modules
- Installation of light guides, SiPMs and readout electronics
- Final assembly of prototype
- Lab testing of prototype with light flasher system and cosmic rays
- Beam test of prototype

All design work needed to fabricate this prototype calorimeter is captured by this WBS line. Procurement of all the mechanical components of the prototype calorimeter is captured by this WBS item.

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.3.3	EMCAL preproduction prototype

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

TECHNICAL SCOPE:

This work package consists of all activities needed to design, procure, and manufacture a full sized prototype sector the Electromagnetic Calorimeter. A sector will be one of 64 sectors which will comprise the EMCAL (32 in azimuth on each side of the spectrometer). The deliverable for this WBS item will be a full sized sector consisting of 24 modules. Each module will consist of an array of 2x8 towers designed to cover a specific region of pseudorapidity. The entire sector will cover one half of the pseudorapidity and one slice of the azimuthal angle of the final calorimeter. The construction of this preproduction prototype sector will test the manufacturing and assembly procedure for producing all of the modules needed for the final calorimeter. It will also test the installation procedure, cable management, and performance of the electronic readout and light pulser calibration systems. Due to its physical size and weight (~ 700 lbs), it will also require designing and testing certain lifting fixtures.

The EMCAL preproduction prototype will be designed to test the calorimeter response over the full rapidity coverage of the final calorimeter. It will also test the production and assembly procedure for constructing an entire sector.

The test program will consist of testing with the light pulser system and cosmic ray triggers. Operation in a beamline, most likely the Fermilab Test Beam Facility, will be carried out in concert with the Inner and Outer HCAL preproduction prototypes.

WORK STATEMENT:

- All mechanical designs of a sector necessary to install it in sPHENIX consistent with the Infrastructure and Installation task is contained in this WBS line. Installation tooling is to be produced as part of the Infrastructure and Installation task.
- Preparation of lifting fixtures, support tables, and workspace needed both for assembly and testing is captured here.
- All activities needed to procure the absorber (tungsten powder, epoxy and scintillating fibers) and any fixtures or devices needed to construct the sector are contained in this WBS line. Thus, all design efforts needed to create production ready drawings are deliverables.
- The full scale preproduction prototype sector will initially be tested in the lab using the light pulser system and with cosmic rays. It will then be tested in the beam along with the preproduction prototypes of the Inner and Outer HCAL. The EMCAL prototype would be instrumented over the full azimuthal and pseudorapidity range of one sector of the final calorimeter, while it is envisioned that the two HCAL prototypes may be instrumented over only part of this range.

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.4.2	EMCAL module assembly

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

TECHNICAL SCOPE:

This WBS line is meant to capture all the activities needed to take the EMCAL module components procured under WBS 1.5.4.1 and assemble them into operational sectors which can be tested as part of WBS 1.5.4.3. The major part of the work will consist of assembling parts (absorber, light collection and SiPM's) and providing workspace for acceptance testing of the modules.

WORK STATEMENT:

- Absorber blocks will be assembled into modules
- Light guides will be attached to each tower
- SiPMs and front end electronic readout will be installed
- Calibration system will be installed
- Modules will be installed into sectors.
- Remaining parts of calibration and cooling system will be installed
- Cable management and preparation for acceptance testing.
- Completing sector assembly with light-tight covers making each sector individually capable of being tested

WBS Dictionary

sPHENIX	03/09/2015	C.Woody, S.Stoll

4. WBS Element Code	5. WBS Element Title
1.5.4.3	EMCAL module/testing/calibration/integration

6. Index Line Number:	7. Revision Number and Authorization:	8: Rev. Date

9. Approved Changes

9. Element Task Description

COST CONTENT:

TECHNICAL SCOPE:

Fully assembled sectors of EMCAL modules are tested and calibrated with the light pulser system and cosmic rays. In order to accomplish this, the controller is powered and bias is supplied by the production bias supply. Measurements of the leakage currents from each calorimeter tower are made and recorded.

Acceptance criteria require that any bias current draw outside three sigma of the mean observed in the prototypes is investigated and repaired if necessary. Testing with the preamplifier test pulse and light pulser are used to verify that each channel is working.

WORK STATEMENT:

- Connection of power, bias cables, communication, and signal cables to preamplifiers, and connection to one or more test racks of electronics.
- Measurement of bias current and debugging of any mis-connected photodetectors or light leaks.
- Measurement of light pulses from each channel
- Setup of trigger counters for cosmic ray testing.
- Collection of cosmic ray data from all channels.
- Data logging and record keeping for each module.